Tracking in LArSoft

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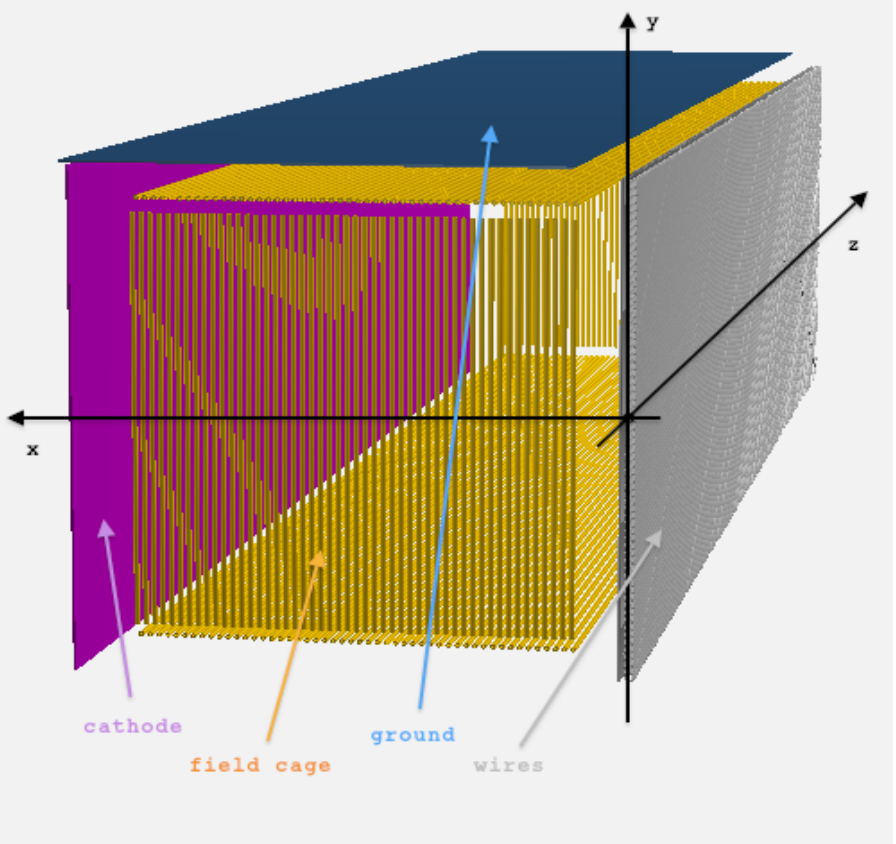
Outline

- The LArSoft global coordinate system.
- Accessing detector and geometry information.
- RecoBase objects for tracking.
- Tracking strategies.
- Track calorimetry.
- Tasks.

The LArSoft Global Coordinate System



- Electrons drift in the *x* direction.

Accessing Detector and Geometry Information

- Geometry service provides geometric information about specific components.
  - CryostatGeo – Information about one cryostat.
  - TPCGeo – Information about one TPC.
  - PlaneGeo – Information about one readout wire plane.
  - WireGeo – Information one readout wire.
- LArProperties service.
  - Drift velocity.
- DetectorProperties service.
  - Sampling rate.
  - Trigger time offset.

RecoBase Objects Used for Tracking

- Hit
  - Measures drift time of one charge deposition on one wire.
  - Drift time $\rightarrow x$.
  - Wire number $\rightarrow z \cos\theta + y \sin\theta$.
- SpacePoint
  - Combination of two or more Hits are used to reconstruct 3D space point in global coordinate system (x,y,z).

Reconstructing Space Points from Hits

- Each Hit contains two degrees of freedom: (time, wire position).
- Two Hits in different views contain four degrees of freedom.
  - (x,y,z) + 1C.
  - 1C = time difference of Hits.
- Three Hits in different views contain six degrees of freedom.
  - (x,y,z) + 3C.
  - 2C = time difference of Hits.
  - 1C = spatial separation of wires.

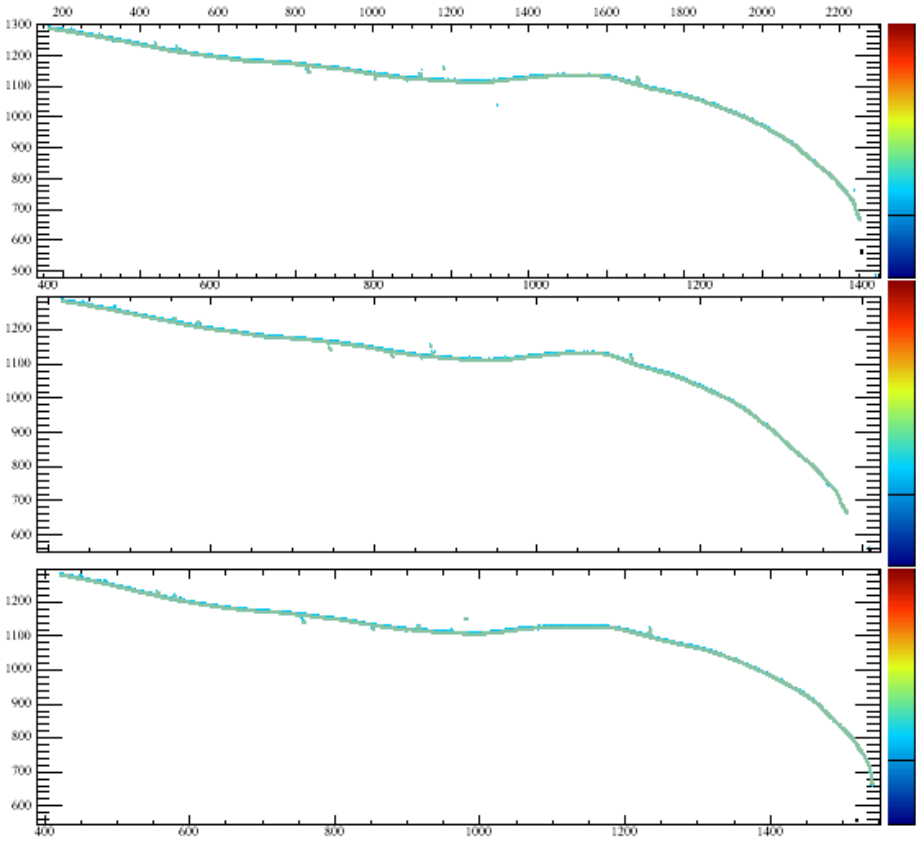
The Parallel Track Problem

Why LAr TPC ≠ Electronic Bubble Chamber

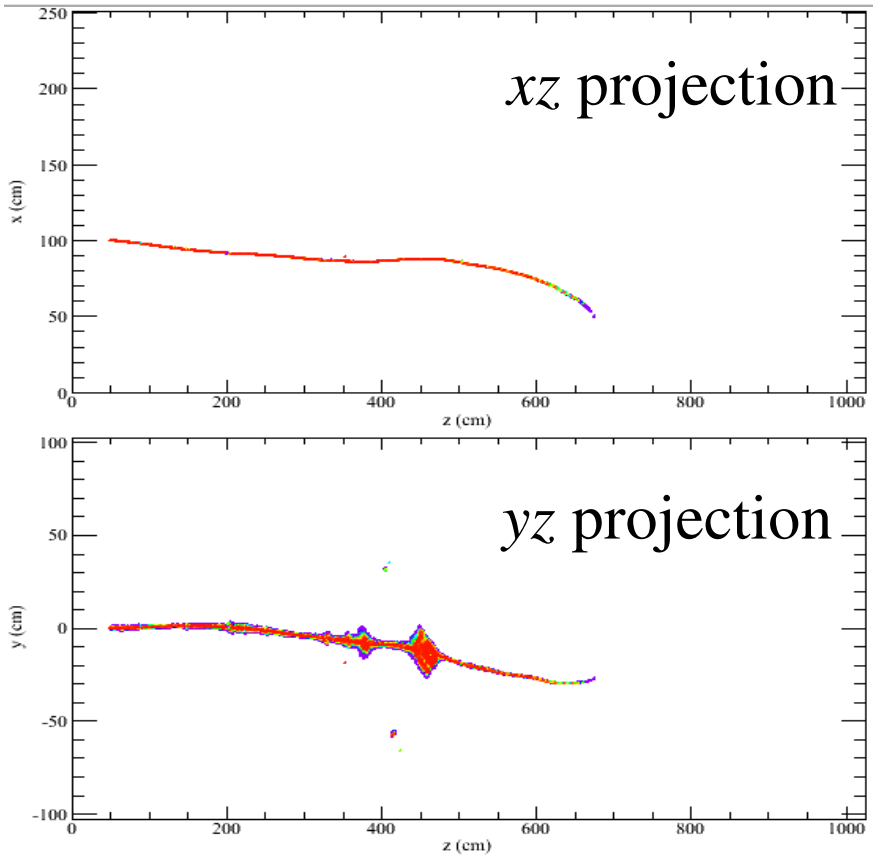
- It is not possible to reconstruct a track traveling parallel to wire planes in 3D because there is no way to match Hits from different views.
  - Time difference information is useless (time difference is the same for each combination of Hits).
  - Space separation doesn't save you either. Since every wire (over a wide range) has a Hit, space-compatible triplets of wires fill the *yz* plane densely.
- What does save you (hopefully) is that the track will bend or scatter out of the plane eventually.

Space Point Reconstruction Example (MicroBooNE single muon)

Wire-Time View (Hits)



Ortho 3D View (SpacePoints)



Strategies for 3D Track Reconstruction

- 2D track reconstruction.
  - Find 2D tracks in each view using Hits as input.
  - Combine views to make 3D tracks.
  - Argoneut used this strategy.
- 3D track reconstruction using SpacePoints.
  - First reconstruct all possible SpacePoints using Hits as input.
  - Find 3D tracks using SpacePoints as input.
- 3D track reconstruction using Hits.
  - Reconstruct 3D tracks directly from Hits.

Tracking in Argoneut

- Standard Reco (job/standard_reco.fcl) contains the following track reconstruction modules which were used for argoneut reconstruction.
  - HoughLineFinder.
    - 2D track reconstruction using Hough Transform (histogram method).
  - LineMerger.
    - Combine 2D track segments into larger 2D tracks.
  - Track3Dreco.
    - Combine 2D tracks in different views into 3D tracks.
- These modules assume straight tracks, and therefore don't work well with larger TPCs (even nonmagnetic ones).
- The 2D track reconstruction strategy could still be viable without the assumption of straight tracks (not being worked on).

3D Kalman Filter for Space Points

- Module Track3DKalmanSPS (Eric Church) implements 3D track reconstruction using the Kalman Filter algorithm with reconstructed SpacePoints as input.
  - SpacePoints are reconstructed from Hits using SpacePointService service.
  - Based on Genfit general purpose Kalman Filter software package.
- Module is partly working.
  - No real solution as yet for parallel track problem (how to choose the correct space points among the large combinatoric background).

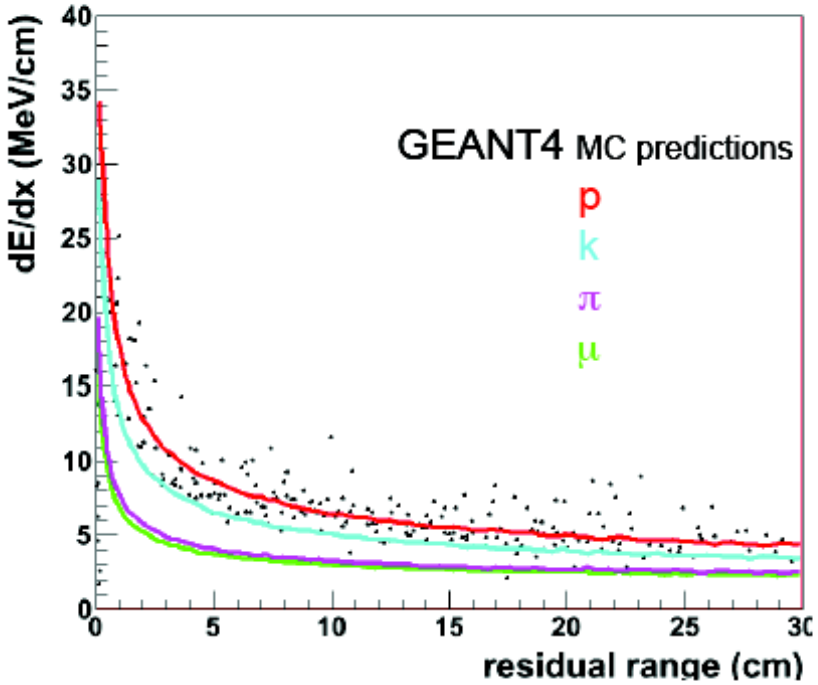
3D Kalman Filter for Hits

- I have been urging larsoft to mount a new effort to develop a Kalman Filter algorithm for track reconstruction directly from Hits. I believe such an effort will be mounted.
  - This approach will avoid the combinatoric fake aspect of the parallel track problem, and should handle the degradation of 3D resolution as well as it can be handled.
  - No code has been written as yet.

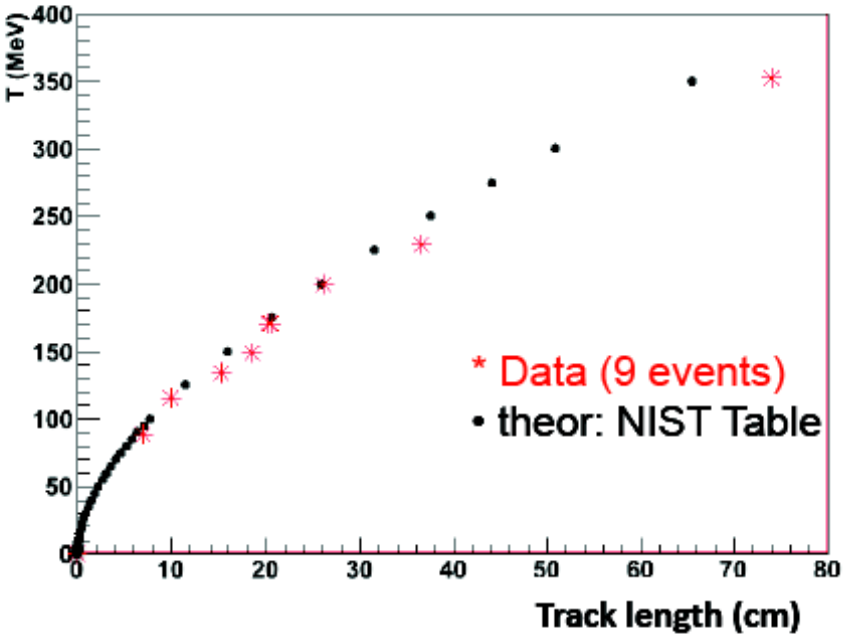
Track Calorimetry (dE/dx)

- Ornella Palamara has been studying this for argoneut data – should extrapolate to other LAr TPCs (once we have tracks).

Argoneut data (protons)



NIST predictions (**Stopping-Power and Range Tables**)



Calorimetric reconstruction of protons:
very good agreement with expectations!

ArgoNeuT

Tasks (Effort Needed)

- There is as yet no out-of-box working larsoft track reconstruction for large TPCs. More effort could be used in any of the three track reconstruction strategies mentioned earlier.
  - I believe the 2D/Hit and 3D/Hit strategies are the most promising, but the 3D/SpacePoint strategy is not dead either.
    - Only the 3D/SpacePoint strategy (Track3DKalmanSPS) has been tried so far.
    - There is still room to try to develop new ways of choosing or merging reconstructed space points.
- Vertex reconstruction (2D or 3D). I would give higher priority to 3D vertex reconstruction, since we expect to have 3D tracks.
  - No one working on it.

Tasks (Cont.)

- Track calorimetry.
- Using multiple scattering and range to measure momentum in nonmagnetic LAr TPC.

Summary

- RecoBase objects used as input for track reconstruction.
  - Hits.
  - SpacePoints.
- 3D reconstruction of SpacePoints from Hits.
  - Parallel track problem.
- Track reconstruction strategies.
  - 2D/Hit.
  - 3D/SpacePoint.
  - 3D/Hit.
- Track calorimetry.
- Tasks (where you can contribute).